

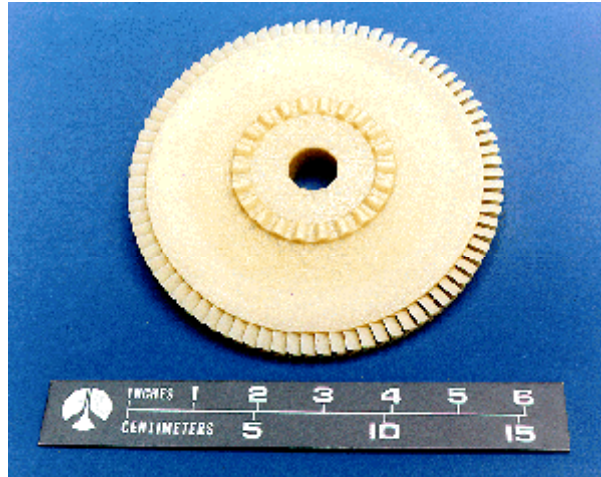
Ceramic Composites Used in High-Speed Turbines for Rocket Engines

Ceramic matrix composite (CMC) technology offers many benefits for liquid-fueled rocket engines. Analyses show that components made from fiber-reinforced ceramic matrix composites (FRCMC's) offer the opportunity for revolutionary gains in turbomachinery performance. In addition, they offer reduced weight and the potential for longer life and lower operating costs. A NASA-sponsored turbopump development effort, conducted at Rocketdyne with parallel material characterization at the NASA Lewis Research Center, confirmed the potential to use FRCMC's for complex turbomachinery components.

The selected FRCMC, C/SiC, is a two-dimensional carbon-fiber-reinforced silicon carbide prepared by chemical vapor infiltration. Results to date on two-dimensional C/SiC coupons and airfoil shapes are encouraging and support the eventual application of FRCMC in advanced rocket engines. Resistance of test coupons to thermal and mechanical fatigue is outstanding, and their ability to survive in a hydrogen-rich steam environment is very good. However, several issues require resolution. Fatigue tests were conducted on representative specimens, but these were limited to a maximum of 10^6 cycles versus a baseline operating life of 10^9 cycles. Also, tests were run independently, and the effects of simultaneous application of thermal and mechanical loads within the combustion environment need to be evaluated.

Available coupon test facilities are limited in their ability to evaluate these combined effects. Subelement tests of stator vanes show the ability of a complex fabricated FRCMC shape to endure severe combined thermal and mechanical loads. Modeling of these subelements validated the ability to analyze these complex materials. However, full-scale turbopump testing will ultimately be required to provide fully representative conditions.

The fabrication and test of a full-scale turbopump component (stator) are the subject of a current program. The stator test is scheduled for early in fiscal 1996 at the Air Force Phillips Laboratory. Pretest and post-test characterizations are being done by the Air Force Wright Laboratories. An unbladed turbine rotor was successfully spun to burst. Burst occurred at 76,889 rpm (128 percent of rated speed) at a projected stress 64 percent greater than the nominal operating stress. The final design of an FRCMC rotor is complete. A selected laser-sintered prototype of this rotor is shown in the figure. Future full-scale component tests of fully bladed rotors will provide the final demonstration of material capability. The next logical step is to fabricate and test a bladed rotor and insert the technology into a flight-scale turbopump.



Selective laser sintered (rapid prototype model) of a fully bladed rotor.

Bibliography

Brockmeyer, J.W.; and Schnittgrund, G.D.: Fiber-Reinforced Ceramic Composites for Earth-to- Orbit Rocket Engine Turbines. Final Report. NASA CR-185264, 1996.

Brockmeyer, J.W.: Ceramic Matrix Composite Applications in Advanced Liquid Fuel Rocket Engine Turbomachinery. ASME, J. Eng. Gas Turbines Power, vol. 115, no. 1, 1993, pp. 58-63.

Eckel, A.J., et al.: Thermal Shock Fiber-Reinforced Ceramic Matrix Composites. Ceram. Eng. Sci. Proc., vol. 13, no. 7-8, 1991, pp. 1500-1508.

Herbell, T.P.; Eckel, A.J.; and Brockmeyer, J.W.: Composites in High Speed Turbines for Rocket Engines. High Temperature High Performance Materials for Rocket Engines and Aerospace Applications. TMS, 1995, pp. 13-20.